12. Data Rates

SNIP recommends that each data relay satellite IOL be able to support the following ranges of source data rate :

For forward links :

100 kbit/s - 25 Mbit/s (BPSK and UQPSK)
100 kbit/s - 50 Mbit/s (QPSK)

For return links :

100 kbit/s - 75 Mbit/s (with coding; BPSK, UQPSK)
100 kbit/s - 150 Mbit/s (no coding; BPSK, UQPSK, QPSK)
100 kbit/s - 150 Mbit/s (with coding; QPSK)

Note Support of higher return link data rates, above about 30 Mbit/s, will be dependent on the availability of decoder equipment in the ground terminals compatible with the coder in the user spacecraft. Currently, ESA, NASA and NASDA coding guidelines follow different concepts.

However, NASA TDRS H, I, J satellites will provide an alternative channel bandwidth of 650 MHz, NASDA DRTS satellites will provide a channel bandwidth of 300 MHz and ESA ARTEMIS and DRS satellites will provide up to three return channels simultaneously on each IOL.

Recommendation 13-3

DATA RELAY SATELLITE CHANNEL PLANS FOR THE 23 AND 26 GHZ BANDS

The SFCG,

CONSIDERING

a) that the frequency bands 22.55 - 23.55 GHz and 25.25 - 27.50 GHz are allocated to the inter-satellite service,

b) that the band 22.55 - 23.55 GHz is recommended for forward inter-orbit links from geostationary data relay satellites (DRS) to low-orbiting spacecraft and the band 25.25 - 27.5 GHz is recommended for return inter-orbit links from low-orbiting spacecraft to DRSs (Recommendation ITU-R SA.1019);

c) that data relay satellites are planned to use these bands for inter-orbit links;

d) that ESA, NASA and NASDA through the Space Networks Interoperability Panel (SNIP) have recommended that data relay satellites be designed to allow interoperable cross-support of each other's user spacecraft.

e) that SNIP has recommended a standard channel plan in these frequency bands;

RECOMMENDS

1. that DRS systems using the 22.55 - 23.55 GHz band for forward inter-orbit links use the following channel centre frequencies:

23.205	GHz
23.265	GHz
23.325	GHz
23.385	GHz
23.445	GHz
23.505	GHz

2. that these forward channels have a minimum bandwidth of 30 MHz;

3. that DRS systems using the 25.25 - 27.50 GHz band for return inter-orbit links use the following channel centre frequencies:

25.600	GHz
25.850	GHz
26.100	GHz
26.350	GHz
26.600	GHz
26.850	GHz
27.100	GHz
27.350	GHz

4. that these return channels have a minimum bandwidth of 225 MHz;

5. that data relay satellites be able to transmit forward signals on either left-hand or right-hand circular polarisation, and receive return signals on either the same or opposite polarisations;

6. that data relay satellites transmitting a tracking beacon in these bands use one of the following frequencies;

23.530	GHz
23.535	GHz
23.540	GHz
23.545	GHz

7. that such tracking beacons be transmitted with left-hand circular polarisation.

U.S. DEPARTMENT OF COMMERCE
NATIONAL TELECOMMUNICATIONS
AND INFORMATION ADMINISTRATION

.IFICATION OF SPECTRUM SUPPORT

Classification	Control Number
UNCLASSIFIED	

Recipient Agency	System	Stage of Review
NASA (Code O)	Proximity Operations Communication System	1 - Conceptual

Section 1: OPERATING CHARACTERISTICS FOR WHICH SUPPORT IS CERTIFIED

Frequency Bands (MHz)	Emission	Power	Station Class (Stage 4)	Operating Location
25250 - 25550 27100 - 27500	22M0G7DDT	1 W	EH, EW	Space

Section 2: SOURCE DOCUMENTS

Docket Number	Description of Document	Dated
SPS-10056	NASA Request for Stage 1 System Review	August 23, 1994
SPS-10269	NTIA Preliminary Assessment	March 3, 1995

Section 3: SPS RECOMMENDATIONS

The Spectrum Planning Subcommittee has reviewed this system under the provisions of Chapter 10 of the NTIA Manual, and recommends that:

1. NTIA certify Stage 1 spectrum support for the Proximity Operations Communication System.
2. NASA be aware that this system, if it progresses to Stage 4, must operate on an unprotected, non-interference basis unless the results of WARC-92 are implemented.
3. NASA, as part of any subsequent request for system review, provide all necessary data to assess this system's conformance with NTIA technical standards and PFD limits, and ensure that the system will meet these standards and limits.
4. NASA submit Appendix 3 and Appendix 4 data to the SSG in a timely manner.
5. NASA ensure that personnel are protected from radiation levels that exceed generally accepted exposure criteria.

Name/Title of Recommending Official	Signature	Date
Paul C. Roosa, Chairman Spectrum Planning Subcommitee	Paul C. Roosa	April 5, 1995

Section 4: NTIA CERTIFICATION

The Office of Spectrum Management certifies Stage 1 spectrum support for this system.

This office concurs with the SPS recommendations in Section 3.

Name/Title of Certifying Official	Signature	Date
William D. Gamble Deputy Associate Administrator	W D Gamble	April 5, 1995

Downgrading Instructions	Classification	Distribution
	UNCLASSIFIED	IRAC, SPS, FAS

Recommendation 15-2
(Provisional)

USE OF THE BAND 25.25-27.5 GHz FOR INTER-SATELLITE (DATA RELAY SATELLITE AND ISS PROXIMITY LINKS) AND EARTH EXPLORATION SATELLITE SERVICE APPLICATIONS

The SFCG

CONSIDERING

a) that Article 8 of the Radio Regulations allocates the 25.25-27.5 GHz band for the inter-satellite service, restricted to space research, Earth exploration-satellite, medical and industrial applications, on a primary basis;

b) that Article 8 of the Radio Regulations also allocates the band 25.5-27.0 GHz to the Earth exploration-satellite service (space-to-Earth) on a secondary basis;

c) that SFCG Recommendation 13-3R1 identifies the standard channel plan adopted by the Space Network Interoperability Panel (SNIP) for use by data relay satellite (DRS) networks;

d) that the International Space Station (ISS) program has requirements for wide band proximity links in the 25.25-27.5 GHz band, for high data rate communications between the Space Station itself and co-orbiting, free-flying radio elements of the program;

e) that studies to identify appropriate criteria to facilitate sharing between the space science services and the fixed service are nearing completion in ITU-R Ad Hoc Joint Study 7B/9D;

RECOMMENDS

1. that the ISS program constrain the implementation of proximity operation communication links to the bands 25.25-25.60 GHz and 27.225-27.5 GHz bands;

2. that DRS systems using the band 25.25-27.5 GHz avoid assignment of channels with the 25.60 GHz and 27.35 GHz centre frequencies for data relay return links to users operating on or near the ISS at times when proximity links are operating in the bands 25.25-25.60 GHz and 27.225-27.5 GHz.

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION
STUDY GROUPS

Revision 1 to
Document 7C/TEMP/11-E
14 March 1996
Original: English only

Source: Document 7C/25

DRAFING GROUP 3

DRAFT REVISION TO RECOMMENDATION ITU-R SA.1024

NECESSARY BANDWIDTHS AND PREFERRED FREQUENCY BANDS FOR DATA TRANSMISSION FROM EARTH EXPLORATION-SATELLITES (NOT INCLUDING METEOROLOGICAL SATELLITES)

ADD new considerings:

g) that additional EES systems requiring space-to-Earth data links are planned, some of which will transmit higher resolution images, requiring high data rates resulting in banwidths greater than can be accommodated in the 8 025 - 8 400 MHz band;

h) that certain future EES systems will require both space-to-space links to data relay satellites and space-to-Earth data links ~~in the same band~~; near 26 GHz.

ADD new recommends 5:

that EES systems requiring wide bandwidth data relay satellite links as well as wide bandwith direct-to-Earth links use assignments near 26 GHz.

ITU-R FACT SHEET

Study Group: WP 7C **Date:** 25 July, 1996

Document: US WP 7C/63 Rev. 1 **Ref:**

Document Title: **ADDITIONAL REQUIREMENTS FOR EESS SPECTRUM**

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Purpose/Objective:

The purpose of this document is to state the rationale for upgrading the allocations for the EESS.

Abstract:

The current and planned missions using the 8025-8400 MHz band for Earth Exploration Satellite Service are catalogued with their spectrum requirements. The affects of expected changes in sensor technology are used to forecast future requirements. The planned usage of the 8025-8400 MHz band and the anticipated requirements for the 25.5 - 27.0 GHz band demonstrate the need to change the worldwide allocations to primary for the EESS in both bands.

Fact Sheet Preparer: Charles Wende

Documents
Radiocommunications
Study Groups
WP 7C
1996

USWP 7C/63 Rev. 1
3 June 1996
Original: English

United States of America

ADDITIONAL REQUIREMENTS FOR EESS SPECTRUM

1 Introduction

This contribution addresses the requirement for additional primary allocations for the Earth Exploration-Satellite Service (EESS). This possibility is included in Resolution GS PLEN-3 from WRC-95 which sets forth the proposed agenda for WRC-97. Agenda item 1.9.2.2 indicates consideration of making EESS allocation at 25.5 - 27.0 GHz primary and extending the primary allocation of 8025-8400 MHz worldwide. This contribution presents information on the state of development of existing and future EESS systems as a basis for indicating the need for additional allocations.

2 The existing allocation

The 8025-8400 MHz band is allocated to the Earth Exploration Satellite Service on a primary basis in ITU Region 2 and on a secondary basis in ITU Regions 1 and 3. The 8025-8400 MHz band is the only band allocated for EESS which is presently both technically and economically feasible for transmission of wide band data from Earth Exploration Satellites directly to Earth. This band is also allocated on a primary basis with the Fixed, Mobile, and Fixed-Satellite (Earth-to-space) Services, and the band 8175-8215 MHz is also shared with the Meteorological-Satellite (Earth-to-space) Service (see Table 1).

The 25.5 - 27.0 GHz band is allocated to the Earth Exploration Satellite Service on a secondary basis worldwide. The technology to support using the 25.5 - 27.0 GHz band has recently been demonstrated by NASA using the Advanced Communications Technology Satellite (ACTS), which operated in the adjacent bands of 27.5 - 30.0 GHz (E-S) and 17.7 - 20.2 GHz (S-E). Presently, Fixed, Mobile, and Inter-Satellite services have primary allocations in the band, while EESS (Space to Earth) and Standard Frequency and Time Signal-Satellites have secondary allocations. (see Table 1).

As a consequence of these multiple services there are sharing criteria in both bands. These include:

- A PFD limit as specified in FN 2570 for the 8025-8400 MHz band.

for EESS space-to-earth use is needed to enable effective planning for the next generation of EESS satellites and their instrumentation.

4 Summary

This contribution shows that the EESS band 8025-8400 MHz is becoming widely used. There are a variety of GSO and NGSO systems which are planning to use all or part of the allocation regularly on a domestic/regional or international basis. These users extend beyond Region 2 and will need the protection that only a primary allocation can provide.

Further, there is inadequate bandwidth in the existing allocation for the next generation of higher resolution systems. The EESS already has a secondary allocation in the 25.5 - 27.0 GHz band, and the technology to use it has recently been demonstrated. This band also needs a worldwide primary allocation to allow the effective planning and development of the next generation of EESS satellites.

TABLE 2.

Present and Future International 8025 - 8400 MHz EESS Systems - June 1996

Satellite Index	Satellite	Administration	Apogee km	Perigee km	Incl. deg.	Lower Freq. MHz	Upper Freq. MHz	Service Area/ Ground Stations	Lat. N/S	Long. E/W	Launch Date
1	ADEOS	Japan	979	979	98.6	8124.4 8243.4 8324.4	8175.6 8256.6 8375.6	Global			17-Aug.-96
2	AVSAT-1	USA-commercial	Geo-stationary	92 deg. W	0	8215	8230	USA			1-Apr-96
3	CLARK	USA	475	475	97.3	8305	8340	Kiruna Fairbanks, AK Longmont, CO	67.9 64.9 40.1	21.1 -147.7 -105.1	Oct-96
4	CRSS-1a (Lockheed)	USA-commercial	680	680	98.1	8025.00 8344.97	8345.00 8345.03	Santa Cruz, CA Marietta, GA	37.2 33.9	-122.2 -89.5	1-Dec-96
5	CRSS-1b (Lockheed)	USA-commercial	680	680	98.1	8025.00 8344.97	8345.00 8345.03	Santa Cruz, CA Marietta, GA	37.2 33.9	-122.2 -89.5	1-Dec-96
6	EARTHWATCH -1A	USA-commercial	600	600	52	8027.9 8105.0	8032.1 8260.0	Longmont, CO Italy Japan USA	40.1	-105.1	1-Feb-1998
7	EARTHWATCH -1B	USA-commercial	600	600	52	8027.9 8105.0	8032.1 8260.0	Longmont, CO Italy Japan USA	40.1	-105.1	1-Feb-1998
8	EARTHWATCH -2A	USA-commercial	468	468	97.3	8305	8340	Scandanavia Fairbanks, AK Longmont, CO	 64.9 40.1	 -147.7 -105.1	Jan.-2001
9	EARTHWATCH -2B	USA-commercial	468	468	97.3	8305	8340	Scandanavia Fairbanks, AK Longmont, CO	 64.9 40.1	 -147.7 -105.1	Jan.-2001
10	ENVISAT-1	France (ESA)	468	468	97.3	8061.5 8161.5 8261.5	8138.5 8238.5 8338.5	Global			1999

TABLE 2 (continued).

Present and Future International 8025 - 8400 MHz EESS Systems - June 1996

Satellite Index	Satellite	Administration	Apogee km	Perigee km	Incl. deg.	Lower Freq. MHz	Upper Freq. MHz	Service Area/ Ground Stations	Lat. N/S	Long. E/W	Launch Date
20	GREENSENSE 1a	South Africa	613	613	97.8	8100 8200	8200.0 8300.0	Global			Jan-97
21	GREENSENSE 1b	South Africa	613	613	97.8	8100 8200	8200.0 8300.0	Global			Jan-97
22	GREENSENSE 1c	South Africa	613	613	97.8	8100 8200	8200.0 8300.0	Global			Jan-97
23	IRS-1A	India	919	890	99.0	8249.75 8305.60	8250.25 8326.40	India			Mar-88
24	IRS-1B	India	900	900	99.0	8249.75 8305.60	8250.25 8326.40	India			29-Aug-91
25	IRS-1C	India	817	817	98.7	8107.50 8254.75 8328.75	8192.50 8255.25 8371.25	India			30-Jun-93
26	JERS-1	Japan	568	658	98.0	8124.2 8324.2	8175.5 8375.5	Global			11-Feb-92
27	LANDSAT-4	USA	686	704	98.2	8127.5	8297.5	Norman, OK Other global sites	35.1	-97.6	16-Jul-82
28	LANDSAT-5	USA	698	720	98.2	8127.5	8297.5	Norman, OK Other global sites	35.1	-97.6	1-Mar-84
29	LANDSAT-7	USA	705	705	98.2	8027.5 8157.5 8287.5	8137.5 8267.5 8397.5	Sioux Falls, SD Other global sites	43.6	-96.6	1-Jan-98
30	MOS-1	Japan	909	909	99.0	8144.0 8344.0	8156.0 8356.0	Esrange Hatoyama Katsuuraa Masuda Okinawa Others	67.9 36.0 35.3 30.5 26.5	21.0 139.3 140.3 131.0 127.9	19-Feb-87

TABLE 2 (continued).

Present and Future International 8025 - 8400 MHz EESS Systems - June 1996

Satellite Index	Satellite	Administration	Apogee km	Perigee km	Incl. deg.	Lower Freq. MHz	Upper Freq. MHz	Service Area/ Ground Stations	Lat. N/S	Long. E/W	Launch Date
42	SPOT-4	France	822	822	98.7	8200.50	8305.50	Kiruna	62.9	21.1	31-Jan-95
						8306.75	8307.25	Aussaguel	43.4	1.5	
								Kourou	5.1	-52.6	
								Other global sites			
43	SPOT-5a	France	822	822	98.7	8200.50	8305.50	Kiruna	62.9	21.1	31-Jan-96
						8306.75	8307.25	Aussaguel	43.4	1.5	
								Kourou	5.1	-52.6	
								Other global sites			
44	SPOT-5b	France	822	822	98.7	8200.50	8305.50	Kiruna	62.9	21.1	31-Jan-98
						8306.75	8307.25	St. Pierre	46.8	-56.3	
								Aussaguel	43.4	1.5	
								Kourou	5.1	-52.6	
								Kerguelen	-51.8	69.1	
46	SSIPR-2	Russia	650	650	98.0	8025.0	8185.0	Russian Territory			10-Oct-92
						8044.0	8084.0	Germany			
						8112.0	8272.0	Poland			
						8240.0	8400.0	Czechoslovakia			
								Hungary			
								Romania			
								Bulgaria			
								Mongolia			
								Viet Nam			
								Cuba			

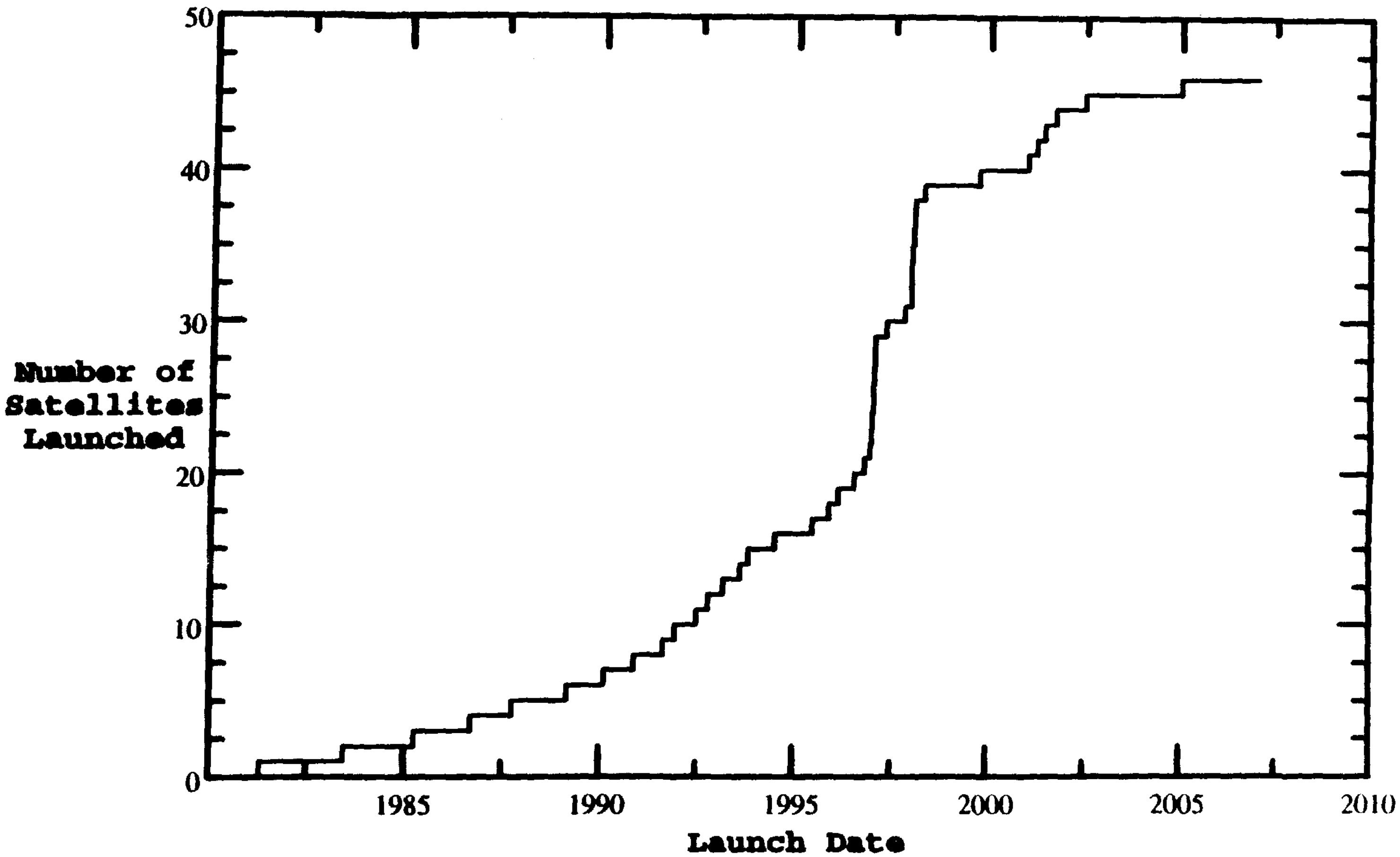

Figure 1. Present and Planned EESS Satellites Using X-Band.

April 17, 1996

Feasibility of Sharing between NASA Space Systems and LMDS systems near 27 GHz

1. Introduction

The National Aeronautics and Space Administration has been asked to examine the sharing feasibility between NASA space services and Local Multipoint Distribution Services below 27.5 GHz. It should be noted that, because of the need to complete this report very quickly, there has been insufficient time to permit a proper review by Goddard Spaceflight Center or Johnson Space Center, the relevant expert NASA Centers. Comments from those Centers may be anticipated in the near future. This report addresses this complex sharing situation, given the system characteristics provided by the LMDS proponents, with the following caveats:

- It was not possible to coordinate the analysis with other space agencies, particularly the European Space Agency (ESA) and the National Space Development Agency of Japan (NASDA), both of which are implementing communications systems that will rely heavily on this frequency band.
- It does not cover specifically planned Department of Defense systems which would operate in this band.
- It does not address the needs of commercial Earth Exploration-satellite systems for high capacity downlinks.

NASA will operate three types of space systems in the band below 27.5 GHz. These are:

- The Tracking and Data Relay Satellite System (TDRS)
- The Proximity Operations Communications System (POCS)
- Earth Exploration Satellite (EES) Service downlinks for NASA satellites

Sharing between LMDS and other space systems operating in the 27.5 - 29.5 GHz band have been studied intensively within the negotiated rulemaking process. The sharing situation between LMDS and EES downlink Earth stations is directly analogous to the sharing situations studied in the negotiated rulemaking, although interference in this case would occur in the EES Earth station rather than the LMDS receivers.

The interference situation between LMDS and TDRS is very different from the LMDS/FSS or LMDS/feeder link situations. Although TDRS systems would not have any Earth stations in this band, the antenna beam of the geostationary TDRS satellite will, of necessity, intersect the Earth at an elevation angle of 0°, creating a direct main beam-to-main beam interference situation with LMDS transmitters.

This report also does not address interference into the LMDS systems. The space systems operating in this band can emit at the levels equal to the PFD limits (RR 2578) for all angles of arrival, including 0°. It is not known if the LMDS proponents have analyzed the effect of this interference.

2. Existing ITU-R documentation

The Radio Regulations contain a limit on the EIRP spectral density emitted by terrestrial systems operating in the 25.25 - 27.5 GHz band (RR2504A), adopted by WARC-92 based on analyses of fixed point-to-point systems. The WARC also asked the then CCIR to study the issue and make a recommendation.

Joint ad hoc 7B/9D was formed to address this issue. Currently within the ad hoc, there is a Preliminary Draft New Recommendation (PDNR) which sets forth EIRP density limits for fixed service stations operating in this band. The recommendation is still under consideration. The basis for the recommendation is analyses of interference into TDRS systems from point-to-point and low density point-to-multipoint systems, as described in the Fixed Service Steering group which provided information on terrestrial systems planned for the band. The PDNR does *not* address high density point-to-multipoint systems such as LMDS

Canada submitted a document to WP 9D concerning its low-density LMCS system sharing with data relay satellites. This document was noted by WP 9D and sent for consideration to Joint Ad Hoc 7B-9D.

3. Space systems operational characteristics

Unless otherwise stated, the space system characteristics given in this section are used in the interference analyses. The three different types of NASA space systems are the Tracking and Data Relay Satellite System (TDRS), the Proximity Operations Communications System (POCS) and NASA Earth Exploration Satellite (EES) service direct ground links.

3.1 TDRS systems

NASA's TDRS system has been used to relay data between user satellites and Earth using S-band and Ku-band frequencies since 1983. The TDRS H, I & J satellites, which are currently under contract and planned for launch starting in 1999, will provide these services in the 25.25 - 27.5 GHz band, as well as in the lower frequency bands, thereby increasing capacity and improving service. The use of 25.25 - 27.5 GHz band is particularly important because of ITU-R Resolution 711 which resolves "that it is desirable to review the present and planned use of the frequency bands 2 025 - 2 110 MHz and 2 200 - 2 290 MHz, with the intent, where practicable, of assigning frequencies to space missions in bands above 20 GHz and possibly reducing the allocations to the space services in the 2 GHz band." Also, the NTIA is encouraging NASA to move data relay satellites out of the Ku-band into the Ka-band, so as to relieve interference situations in that band.

The TDRS 25.25 - 27.5 GHz channels are designed to support data rates ranging from 1 kbps to 800 Mbps. The 800 Mbps data rate is accommodated in a 650 MHz bandwidth and is required to transmit wide-band sensor data. Lower data rates will use bandwidths commensurate with the data rate. The need to support several of these wide band channels within a given orbital area is foreseen.

The hypothetical reference circuit for data relay satellite systems is given in Rec. ITU-R SA. 1018. Characteristics and interference criteria for data relay satellite systems is given in Rec. ITU-R SA. 1155. For the purposes of this analysis, the characteristics of the TDRS receiving system are as follows:

TDRS receive antenna gain	58.0 dBi
TDRS system noise temperature, evaluated at the satellite receiver	-138.0 dBW in 1 MHz
TDRS interference criteria (I/N)	-148.0 dBW in 1 MHz

The -148.0 dBW in 1 MHz interference criteria given above is based on Rec. ITU-R SA.1155 which specifies a maximum aggregate interference level of -178 dBW/kHz not to be exceeded for more than 0.1% of the time, based on satellite orbital period. The TDRS mainbeam will be pointed at any given point near the Earth's limb for about 0.1% of the time, so that the Rec. ITU-R SA.1155 interference criteria would essentially permit one interferer to be pointed at the TDRS orbital location. Because a high density point-to-multipoint system can be expected to have many transmitting antennas pointed at the TDRS, and so the maximum levels of interference would exist for more than 0.1% of the time.

3.2 Proximity Operations Communication System

Future demands on Low Earth orbit communications between space vehicles in close proximity will require reliable, bandwidth efficient links with the capability of high data transmissions. Types of data to be transmitted will range from simple telemetry to color telerobotics video (data rates greater than 100 Mbps). In addition, ESA has stated a requirement for 4 simultaneous channels of 60 Mbps. This type of proximity operations communications system may also have applications to low orbit inter-vehicle communications in future planetary missions. The Proximity Operations Communication System (POCS) has completed Stage 1 review and is being readied for Stage 2 review for operation in the 25.25 - 25.55 GHz and 27.225 - 27.5 GHz bands.

POCS will operate on satellites at altitudes from 280 km to 500 km with inclinations from 28.5 - 57 degrees. The POCS receiving system will utilize a 32.5 dBi antenna and have a system noise temperature of 773 K. The appropriate interference criteria for the POCS system can be found in Rec. ITU-R SA.-609 and is an I/N ratio of -6 dB.

3.3 Earth exploration-satellite downlinks

WARC-92 recognized the need for wide band Earth Exploration-Satellite Service (EES) downlinks near 26 GHz and made a secondary allocation to the service in the band. The band

8,025 - 8,400 MHz, which is currently used by the EES, is becoming congested by users of all of the allocated space services in that band. Advances in technology are providing higher resolution instruments which in turn require ever larger bandwidths to download their data from the spacecraft. For these reasons, a wide band allocation near 26 GHz is essential.

WRC-95, in response to proposals by the United States and India, decided that this issue should be considered further and placed it on the agenda for WRC-97. Agenda item 1.9.4.2 addresses consideration of an allocation to the (EES) near 26 GHz to provide direct downlinks of EES data to Earth.

EES use of the band will consist of satellites in low Earth orbits, typically less than 1,000 km altitude, and geostationary satellites, transmitting directly to Earth stations. Typical sites for Earth stations will be universities and private meteorological organizations in urban areas.

4. LMDS characteristics

Interference into TDRS systems due to emissions from LMDS systems will be evaluated on two bases. The first involves the specific characteristics of LMDS systems as given in section 4.1. The second involves evaluating interference based on the EIRP limit curves contained in Appendix B to the Third NPRM.

4.1 Characteristics used in the analysis

Unless otherwise stated with respect to a specific analysis, the LMDS characteristics used in this analysis are as given in Figure 4-1. These characteristics were selected from the range of values provided. Antenna gain patterns, developed from the information provided, are given in Figures 4-2 and 4-3.

The EIRP/MHz values listed in Figure 4-1 were provided for this study by the LMDS proponents. With one exception, all LMDS signals were digital and no peaking or interleave factor was assumed. CVUS for their hub transmissions specified a wide range of values from 7 dB(W/20 MHz) channel in their existing TV/FM installation in New York to the 25 dB(W/MHz) they have proposed to the FCC for both hub and subscriber transmissions. The existing TV/FM system is estimated to produce a 1 dB(W/MHz) EIRP taking into account a 10 dB peaking factor and a -3 dB interleave factor. The upper and lower bounds of this 24 dB EIRP range were evaluated.

Hub antennas for CVUS and TI are omni-directional in azimuth and were modeled using the equations in Figure 4.2 with one co-frequency signal per hub. The main beam was depressed below the horizon by the value supplied by the proponents (Figure 4-1). Where a range of values was provided, the minimum value was used.

The Endgate hub consists of 36 azimuthal sectors. The HP hub consists of 4 azimuthal sectors. They were modeled as a single toroidal antennas, omnidirectional in azimuth radiating one co-frequency signal per hub under the assumption that signal from one sector would be the dominant interferer in any azimuthal direction.

Subscriber antennas for all proponents exhibited high-gain, circular beams. In general, a large number of LMDS cells are within a spacecraft receiving beam footprint and subject its receiver to the "average" of LMDS subscribers located at random within their respective cell areas. Subscribers were modeled by an "azimuth-averaged" antenna pattern in much the same manner used in the Canadian Report.

A cell area was uniformly populated with subscriber antennas pointing at a hub receiver at 30 meters altitude. At a given reference elevation angle, the necessary pointing angles and resultant subscriber antenna gains, and distance from the hub receiver were calculated for each subscriber. It was assumed that the EIRP of each subscriber was proportional to the square of its distance from the hub receiver and that its elevation angle increased near the hub (flat Earth approximation). The resultant EIRP at the given reference elevation angle was summed over all subscribers within the cell and the result divided by the number of subscribers to arrive at an "average" subscriber EIRP for an LMDS cell. The process was repeated over the range of elevations from 0° to 90°. The result was an "average" subscriber pattern, omnidirectional in azimuth, varying only in elevation valid for the case of 1 co-frequency subscriber per LMDS cell. LMDS sectored-hub systems may accommodate more than one co-frequency subscriber per cell - this case was modeled by increasing the model EIRP in proportion to the maximum number of active subscribers.

	CVUS Hub	CVUS Sub	TI Hub	TI Sub	END Hub	END Sub	HP Hub	HP Sub
EIRPo (dBW/MHz)	25.0[4]	25.0[4]	7.0	17.0	-3.3	-9.7	-8.0	18.0[1]
Cell Radii (km)	see Figure 5-2							
Average Height of Hub above ground (m)	30	30	30	30	30	30	30	30
Elevation of Hub antenna main beam (° from horizon)	-1		-2		-1.5		-0.3	
Transmitter power as a function of subscriber-to-hub distance (dB)		20 log(d)		20 log(d)		20 log(d)		20 log(d)
Peaking factors (dB)[2]	10	0	0	0	0	0	0	0
Interleave factors (dB)	-3	-3						
Maximum percent of area populated by LMDS cells for satellite beams of size:								
144,000					2 - 30		5 - 10	
40,000					10 - 40		10 - 35	
7,000					25 - 85		30 - 70	
Maximum subscriber pointing angle above the horizontal (°)		5		15		15		5.7
Maximum antenna gain (dBi	12	31	15	34	31[3]	40	15	35
Number of Hub antenna sectors	1		1		36		6	

Notes:

1. 18 dBW/MHz for clear sky $EIRP_0$ was assumed based on the 22 dBW/MHz $EIRP_0$ for rain conditions minus 1 dB/km * 4 km cell radius
2. Applicable when the victim bandwidth is much narrower than an FM-TV signal
3. 40 dBi was provided in the data package, but 31 dBi is consistent with the beamwidths given
4. These values were provided by CVUS. In most of the following analyses, values of 1 and 10 dBW/MHz are used for the Hub and Subscriber $EIRP_0$. The 25 dBW/MHz is treated as a separate case.

Figure 4-1. LMDS characteristics provided

CVUS Hub in dB relative to mainbeam gain of 12 dB(i)

$-3(\emptyset/3.27)^2$	$0 \le \emptyset < 10$ degrees
-28	$10 \le \emptyset < 35.8$ degrees
$-0.34\emptyset -15.9$	$35.8 \le \emptyset < 65$ degrees
-38	$65 \le \emptyset \le 90$ degrees

TI Hub in dB relative to mainbeam gain of 15 dB(i):

$-3(\emptyset/3.98)^2$	$0 \le \emptyset < 8.9$ degrees
$6.18 - 2.38\emptyset$	$8.9 \le \emptyset < 11$ degrees
-20	$11 \le \emptyset < 25$ degrees
$-7.5 -0.5\emptyset$	$25 \le \emptyset < 35$ degrees
-25	$35 \le \emptyset \le 90$ degrees

Endgate Hub in dB relative to mainbeam gain of 31 dB(i), 36 sectors:

0	$0 \le \emptyset < 1$ degree
$-10 - 28 \log\emptyset$	$1 \le \emptyset \le 90$ degrees for a single sector

HP Hub in dB relative to mainbeam gain of 15 dB(i), 6 sectors:

Sector Hub, Elevation Plane

$-0.0885\emptyset^2$	$0 \le \emptyset < 10.63$ degrees
-10	$10.63 \le \emptyset < 17.5$ degrees
$26.53 - 29.39 \log\emptyset$	$17.5 \le \emptyset \le 90$ degrees for a single sector

Figure 4-2. Assumed Hub antenna patterns

All patterns are assumed to be circularly symmetrical

CVUS Subscriber in dB relative to mainbeam gain of 31 dB(i):

$-3(\emptyset/2)^2$	$0 \le \emptyset < 4.9$ degrees
-18	$4.9 \le \emptyset < 12$ degrees
-24	$12 \le \emptyset < 50$ degrees
-30	$50 \le \emptyset < 90$ degrees
$99.84 - 66.64 \log\emptyset$	$90 \le \emptyset \le 180$ degrees

TI Subscriber in dB relative to mainbeam gain of 34 dB(i):

0	$0 \le \emptyset < 1$ degrees
$-3.2(\emptyset-1)$	$1 \le \emptyset < 6$ degrees
-16	$6 \le \emptyset < 14$ degrees
$180 - 14\emptyset$	$14 \le \emptyset < 15$ degrees
-30	$15 \le \emptyset \le 180$ degrees

Endgate Subscriber in dB relative to mainbeam gain of 40 dB(i):

$-3(\emptyset/.985)^2$	$0 \le \emptyset < 3$ degrees
$-21-14.5 \log \emptyset$	$3 \le \emptyset \le 180$ degrees

HP Subscriber in dB relative to mainbeam gain of 35 dB(i)

$-1.78\emptyset^2$	$0 \le \emptyset < 3.9$ degrees
-27	$3.9 \le \emptyset < 5$ degrees
$-5.1 - 31.33 \log\emptyset$	$5 \le \emptyset < 13$ degrees
-40	$13 \le \emptyset \le 180$ degrees

Figure 4-3. Assumed subscriber antenna patterns

4.2 Third NPRM EIRP limits

The Third NPRM with respect to LMDS in the 27.5 - 29.5 GHz frequency band provides a proposed EIRP limit on the aggregate power spectral density emitted by an LMDS, averaged over the LMDS system's BTA. For 0° elevation angles, the limits are as follows:

Climate Zone	EIRP Spectral Density (Clear Air) (dBW/MHz-km2)**
1	-23
2	-25
3,4,5	-26

These limits would be reduced (made more restrictive) for higher angles of elevation as follows:

Elevation Angle (a)	Relative EIRP Density (dBW/MHz-km2)
$0° \le a \le 4.0°$	EIRP(a) = EIRP(0) + 20 log (sin πx)(1/ πx) where x = (a + 1)/7.5
$4.0 < a \le 7.7°$	EIRP(a) = EIRP(0) - 3.85a + 7.7
$a > 7.7°$	EIRP(a) = EIRP(0) - 22

where a is the angle in degrees of elevation above horizon. EIRP(0°) is the hub EIRP area density at the horizon used in Section 21.1020. The nominal antenna pattern will be used for elevation angles between 0° and 8°, and average levels will be used for angles beyond 8°, where average levels will be calculated by sampling the antenna patterns in each 1° interval between 8° and 90°, dividing by 83.

The Third NPRM applies these limits to hub emissions only. An analysis by Hewlett-Packard ("Analysis of CPE Tx's Fit to Proposed Rules, 21.1020 & 21.1021 per 3rd NPRM for 28 GHz using Proposed Rules for CPE Tx's in 150 MHz Band") indicated that these limits could also be met by the subscriber emissions. This report will use these limits to analyze interference from both hubs and subscribers.

5. Impact of the modeled LMDS systems on a TDRS

5.1 Effects of single, high powered LMDS emitters on a TDRS

As an initial step in the analysis, the impact of an individual LMDS transmitter pointed at a TDRS receiver was investigated. Table 5-1 presents a calculation of the interference received by a TDRS from each Hub or subscriber, assuming that the TDRS is visible at an elevation angle of 3°. The subscribers are assumed to have an antenna elevation of 1°.

As can be seen in the figure, a single CVUS Hub, CVUS Subscriber or HP subscriber operating at the maximum EIRP densities would produce interference in the TDRS. When the peaking factors are applied, the interference situation becomes much worse. The effect of multiple mainbeam hits would exacerbate the situation.

	CVUS Hub	CVUS Sub	CVUS Hub	CVUS Sub	TI Hub	TI Sub	END Hub	END Sub	HP Hub	HP Sub
EIRPo (dBW/MHz)	25.0	25.0	1.0	10.0	7.0	17.0	-3.3	-9.7	-8.0	18.0
Antenna elevation	-1.0	1.0	-1.0	1.0	-2.0	1.0	-1.0	1.0	-0.3	1.0
Elevation to TDRS	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
LMDS antenna discrimination (dB)	-4.5	-3.0	-4.5	-3.0	-4.7	-3.2	-26.9	-12.0	-3.1	0.0
Space loss to GSO	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5	-213.5
Atmospheric loss(dB)	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0	-6.0
Polarization loss (dB)	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
TDRS Antenna gain	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0
Interference received (dBW/MHz	-144.0	-142.5	-168.0	-157.5	-162.2	-150.7	-194.6	-186.2	-175.5	-146.5
Interference criteria	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0	-148.0
Margin, no peaking (dB)	-4.0	-5.5	20.0	9.5	14.2	2.7	46.6	38.2	27.5	-1.5
Peaking factors	10.0									
Margin, with peaking	-14.0									

Figure 5-1. Impact of single LMDS emitters on a TDRS

5.2 Aggregate effect of LMDS models on a TDRS

The aggregate interference level in a TDRS receiver due to emissions from LMDS subscriber transmitters was evaluated based on the characteristics give in Figure 5-2.

The TDRS is a geostationary satellite whose high-gain receiving 0.15° beam tracks and receives signals from low-orbiting spacecraft. For the majority of the time, the TDRS receiving beam points toward the Earth.

A computer model points the TDRS 0.15° wide beam boresight to intersect the Earth at a specified angle of elevation. The TDRS 3 dB beam area intersection with the Earth is then fully populated with LMDS cells equally spaced using the cell radius from Figure 5-2. The necessary pointing angle, slant range, antenna gain, and clear-air atmospheric loss calculations (ITU-R PN.676-2) are made to determine the interfering power contribution from each cell. The aggregate interference power for 100% LMDS deployment is accumulated for a particular angle of elevation of the TDRS mainbeam boresight. The process is repeated for elevation angles from 0° to 90°.

For a 90° elevation angle, the TDRS beam intersection with the Earth is a circle of about 94 km diameter. A 100% "fill" of the beam area would be appropriate for high elevation angles.

For low elevation angles, the beam intersection takes on an elongated elliptical area of about 160 km wide and up to 1200 km long. A 33% "fill" of the beam area may be more appropriate for low elevation angles and is estimated by assuming LMDS interference levels are reduced by 10 log(33%/100%) = -4.8 dB.

Figure 5-2 lists the cases that were examined and the LMDS parameters used. With the exception of CVUS TV/FM hub transmissions, digital signals were specified by the proponents. It was found that the EIRP/MHz was essentially independent of the bandwidth and data rate of the several signals provided by each proponent.

The results for LMDS Hub transmissions were made on the basis of one co-channel signal per cell and are shown on Figure 5-3. The curves correspond to the labeled rain zone areas (1, 2, 3-5) from Table 5-2, and are shown for 33% fill of the beam area.

For CVUS hubs, the top 3 curves are for an EIRP of 1 dB(W/MHz) matching their existing New York system for the 3 rain zones. The interference margin to TDRS is negative for elevation angles below 10°. The lower curve illustrates the disastrous effect of a 25 dB(W/MHz) EIRP.

The TI and HP systems both show negative margins for elevation angles below 10°.

Endgate hubs show a positive margin for all elevation angles.

The results for LMDS subscriber transmissions were made on the basis of one co-channel signal per cell and are shown on Figure 5-4. The curves correspond to the labeled rain zone areas (1, 2, 3-5) from Table 5-2, and are shown for 33% fill of the beam area.

CVUS subscribers show a small positive margin for the 10 dB(W/MHz) value used for the Canadian LMCS system and a negative margin for all elevation angles for the 25 dB(W/MHz) limit that CVUS has proposed to the FCC.

Endgate subscribers show a large positive margin on the basis of 1 subscriber per cell. However, their 36 sector hub with full frequency reuse allows a maximum of 36 subscriber transmissions per cell which would reduce the margins by 15.6 dB for the higher angles of elevation, (that is, away from the hub antenna mainbeam). The HP system shows positive margins for most conditions.

TI subscribers cause a negative margin at low elevation angles.

See Appendix A, Figures A-1 and A-2 used in deriving the interference margin plots shown in Figures 5-3 and 5-4. The margins in these figures are for a 33% fill of the satellite beam footprint area.

Case name	EIRP/M Hz	Rain Zone	Cell Radius	Location
CV Sub 1	10.0	1	2.7	Miami
CV Sub 2	10.0	2	4.8	New York
CV Sub 3	10.0	3	9.5	San Francisco
CV Sub 1 - 25	25.0	1	2.7	Miami
END Sub 1	-9.7	1	4.5	Miami
END Sub 2	-9.7	2	7.6	New York
END Sub 3	-9.7	3	15	San Francisco
HP Sub 1	18.0	1	1	Miami
HP Sub 2	18.0	2	4*	New York
HP Sub 3	18.0	3	4*	San Francisco
TI Sub 1	17.0	1	2.5	Miami
TI Sub 2	17.0	2	5	New York
TI Sub 3	17.0	3	5	San Francisco
CV Hub 1	1.0	1	2.7	Miami
CV Hub 2	1.0	2	4.8	New York
CV Hub 3	1.0	3	9.5	San Francisco
CV Hub 1 - 25	25.0	1	2.7	Miami
END Hub 1	-3.3	1	4.5	Miami
END Hub 2	-3.3	2	7.6	New York
END Hub 3	-3.3	3	15	San Francisco
HP Hub 1	-8.0	1	0.5	Miami
HP Hub 2	-8.0	2	4	New York
HP Hub 3	-8.0	3	4	San Francisco
TI Hub 1	7.0	1	2.5	Miami
TI Hub 2	7.0	2	5	New York
TI Hub 3	7.0	3	5	San Francisco

Note: Late information received from HP indicated that these values should be 2 km radii. This would reduce the margin for interference received from these links by 6 dB.

Figure 5-2. LMDS Hub and Subscriber cases